The Canadian Geographer
Le Géographe canadien
Canadian Association of Geographers
Association Canadienne des Géographes

Visualizing the directional bias in property crime incidents for five Canadian municipalities

Richard Frank
School of Criminology, Institute for Canadian Urban Research Studies, Simon Fraser University

Martin A. Andresen
School of Criminology, Institute for Canadian Urban Research Studies, Simon Fraser University

Patricia L. Brantingham
School of Criminology, Institute for Canadian Urban Research Studies, Simon Fraser University

There are three interconnected and fundamental elements that define the spatiality of crime: places, distances, and directions. Over the past 180 years, research has flourished for the first two fundamental elements with relatively little research on directionality. In this article, we develop a visualization technique allowing for the display of the directional bias for a large number of offenders that aids in subsequent analysis. We show that a directional bias in criminal activity is present overall, but is not monolithic. Consequently, urban form and understanding place play a strong role in criminal directional biases for moving through our environments.

Keywords: directionality, geography of crime, visualization

Se représenter le biais directionnel de l'incidence du crime contre la propriété dans cinq municipalités canadiennes

Il existe trois éléments reliés et fondamentaux pour définir le rapport entre le crime et l'espace : les lieux, les distances et les directions. Au cours des 180 dernières années, les recherches se sont multipliées portant sur les deux premiers éléments fondamentaux aux dépens de la question de la directionnalité. Dans cet article, nous élaborons une technique de représentation visuelle permettant de mettre en relief le biais directionnel d'un grand nombre de contrevenants dans l'optique d'améliorer les analyses ultérieures. Il se dégage que, dans l'ensemble, un biais directionnel existe au niveau des activités criminelles sans être monolithique. Par conséquent, la forme urbaine et la connaissance du lieu jouent un rôle de premier plan dans les biais directionnels de la criminalité qui traversent nos milieux de vie.

Mots clés : directionnalité, géographie de la criminalité, représentation visuelle

Introduction

Investigations into the geography of crime date back 180 years to the work of Quetelet (1831, 1842) and Guerry (1833). During the early twentieth century, the geography of crime followed the work of the Chicago School (Burgess 1916; Shaw and McKay 1931, 1942), but more recently much of this research has been undertaken under the auspices of environmental criminology (Cohen and Felson 1979; Felson and Cohen 1980, 1981; Brantingham and Brantingham 1981, 1984; Clarke and Cornish 1985; Cornish and Clarke 1986). Because of this more recent work, our understanding of the geography of crime has advanced significantly in recent years (Ratcliffe 2002).

Within the geography of crime research, there are three interconnected and fundamental elements: places, distances, and directions.[1] Indeed, the first two of these elements (place and

Correspondence to/Adresse de correspondance: Martin A. Andresen, School of Criminology, Institute for Canadian Urban Research Studies, Simon Fraser University, 8888 University Drive, Burnaby, BC V5A 1S6. Email/Courriel: andresen@sfu.ca

[1] In other aspects of criminological research, offender and victim characteristics are the primary variables of interest.

The Canadian Geographer / Le Géographe canadien 2013, 57(1): 31–42
DOI: 10.1111/j.1541-0064.2012.00450.x
© Canadian Association of Geographers / L'Association canadienne des géographes

distance) are well-researched areas within the geography of crime. Much of the Chicago School research focused on places (neighbourhoods), and the recent work on "crime at places" focusing on micro-spatial units of analysis, such as the street segment, significantly advances our knowledge of the geography of crime (see Sherman et al. 1989; Eck and Weisburd 1995; Taylor 1997; Smith et al. 2000; Weisburd, Bushway et al. 2004; Weisburd et al. 2009; Andresen and Malleson 2011).

Not only does the journey to crime (distance) have theoretical relevance (Brantingham and Brantingham 1981), but empirical research consistently shows the journey to crime is short, particularly for violent crime and the young offender[2] (Pyle et al. 1974; Phillips 1980; Castanzo et al. 1986; LeBeau 1987; Wiles and Costello 2000; Bernasco and Block 2009)—see van Koppen and De Keijser (1997) and Rengert et al. (1999) for discussions on the issue of the distance decay functions as a representation of the rate at which offending decreases as the distance from home increases.

The third fundamental element (direction) is an under-researched area in the geography of crime. The research of White (1932), Brantingham and Brantingham (1981, 1984), Rengert and Wasilchick (1985, 2000), and Ratcliffe (2006) considers the importance of directionality for the geography of crime from a theoretical perspective: because of the constrained nature of our built and temporal environment, we tend to develop specific routes between frequently visited destinations. As such, directionality emerges as a consistent pattern over time. Considering that most criminal activities take place within the same spaces of our legitimate activities (Brantingham and Brantingham 1981, 1984), criminal activities have a directional bias as well.

One of the difficulties in the directionality research is the visualization of directional bias. The construction of a directional bias requires the calculation of a geometry, based on reported occurrences that fall within a circumscribed angle in relation to a specific location: the percentage of crime trips that fall within a 45 degree angle from home, for example. Visualizing this directional bias is critical for understanding why a directionality bias may be present. Consequently, visualization in this research is a stepping-stone to the analysis of directionality. On the basis of a reported directional bias, questions can be asked: are individual offenders attracted to particular locations? Are all offenders attracted to particular locations? Does the strength of directionality vary from place to place? Rengert and Wasilchick (1985, 2000) use a "protractor method" to measure the directional bias of residential burglars.[3] This method is instructive for a relatively small number of individual offenders but not for a large data set. A visualization procedure is needed that properly communicates directional bias information for a large data set without cluttering the map with excessive symbols (Tufte 2001).

In this article, we develop and present such a visualization procedure. This visualization procedure considers all offenders and individual criminal incidents for entire municipalities. A total of five municipalities are used to show the varying degrees of directionality bias and the importance of understanding place. Overall, a strong directionality bias is present; this directionality bias is explained considering urban form, place, and criminal opportunity.

The importance of visualizing criminal activity

Visualizing criminal activity, crime mapping, has a long history that coincides with the geography of crime literature. Quetelet's (1842) maps of violent and property crimes in French departments begins the literature on this subject. Later North American examples include Shaw and McKay's (1942) maps of neighbourhoods in Chicago that are some of the earliest, well-known, examples of this activity—not to mention "pin-maps" shown in police departments, primarily on television. However, crime mapping as a common tool of investigation did not emerge until the 1980s with the introduction of lower cost, easy to use

[2]Because of this theoretical relevance and empirical support, the journey to crime is important with regard to practical/tactical application, especially in policing with geographic profiling (Rossmo 2000).

[3]This method places the vertex of the protractor at the home location of the burglar and then counts the criminal events committed by that burglar within angular measures.

computers with mapping and off-the-shelf software. These developments coincided with the computerization of police records that allowed for their use in crime and intelligence analysis. This aided crime analysts in identifying previously unknown patterns or obtaining better knowledge regarding patterns in crime (Ratcliffe and McCullagh 2001; Ratcliffe 2004; Chainey and Ratcliffe 2005). Though the development of crime mapping encountered a number of hurdles, it is now well established in the United States, Canada, the United Kingdom, Australia, South Africa, and South America (Chainey and Ratcliffe 2005).

Crime mapping currently has a wide variety of applications. It is used as an information system, recording and mapping police activity; for problem-solving in crime analysis; for geographic profiling of serial offenders; and for program monitoring and evaluation (Chainey and Ratcliffe 2005). The technologies for crime mapping are evolving rapidly, with current research being developed in spatio-temporal crime analysis, 4D applications (Wolff and Asche 2009), as well as the development of software and/or extensions specifically for crime analysis: Esri's ArcGIS (Esri n.d.), which has applications for crime analysis, and stand-alone systems such as GeoVista's CrimeViz (2010). The mapping of directionality, however, is all but non-existent though it provides meaningful information to the study of the geography of crime because our tendency for directional behaviour is well established.

Directionality bias and crime: Theory and evidence

It is a tenet of spatial-decision making in geography that, in any activity within our urban environments, we assimilate information about that environment that subsequently influences decisions (Wolpert 1964; Horton and Reynolds 1971; Lowe and Moryadas 1975; Rengert 1989). Fundamental to understanding these decisions is the premise that individuals adapt to their urban spatial structure and that the individual relates personally to the structure s/he inhabits. Typically, the centre of each person's environment is assumed to be the home (Horton and Reynolds 1971), with most of our time spent at a number of activity nodes (home, work, school, recreation sites, entertainment, and shopping) and the pathways between them (roads and walkways). Consequently, nodes and pathways constitute the areas within our (urban) environment that define our activity and awareness spaces (Lynch 1960).

In the work of Brantingham and Brantingham (1981, 1984, 1993), these spaces are shown on maps that outline why a directional bias is expected in criminal behaviour. This directional bias may be strong or weak, as shown in Figure 1. Figure 1a, strong directionality, shows the vast majority of one person's activities restricted to a 45-degree angle, whereas Figure 1b, weak directionality, shows the person travelling in all directions. Consequently, the strength of directional bias depends on the relative frequency of strong and weak directionality activity spaces in the general population.

Rengert and Wasilchick (1985, 2000) produced the first known studies of directional bias in criminal behaviour. In considering residential burglary, they find that at least 50 percent of burglaries occur within a 45-degree angle from the home location of the criminal; this is 12.5 percent of the potential use of space. Moreover, if only burglars with legitimate employment are considered, close to 75 percent of their burglaries are contained within a 45 degree angle from the home location and are in close proximity to the work place or along the primary pathway between work and home—most peoples' primary activity nodes.

Aside from this initial empirical verification, we only know of three other criminological studies that sought to verify directionality bias empirically.[4] Castanzo et al. (1986) tested whether or not offenders who live close to one another travel in the same direction when committing their offenses. The authors found that offenders living close to one another consistently moved in similar directions to commit their offenses, regardless of the crime classification. In another study of directionality and serial homicide, Godwin (2001) found that serial murderers are directionally biased for both target selection and the disposal of bodies.

[4]Pyle et al. (1974) find that most offenders are drawn towards urban centres, but they do not investigate directional bias, *per se*.

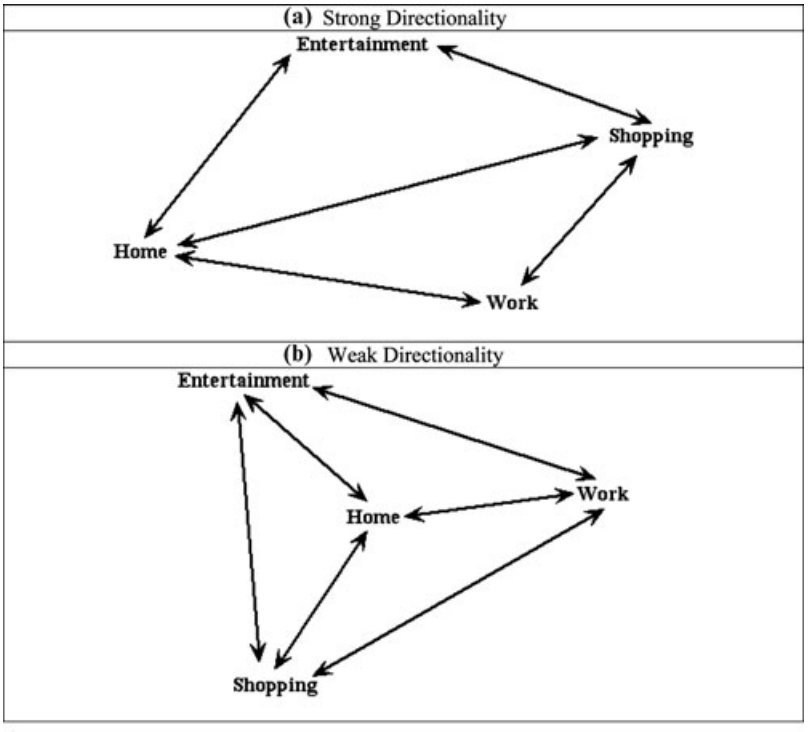

Figure 1
Geometry of crime.

A primary limitation of the above empirical research was their sample sizes. Small samples make generalizations for criminal directional bias difficult. Subsequent empirical research employing a large sample, approximately 19 000, investigated the travel patterns of offenders (Costello and Wiles 2001) and found that offenders do have a directional bias towards urban areas, but there is no indication of the strength of that bias.

In this article, we use a large data set developed by law enforcement officials in British Columbia, Canada, to test the idea of directionality as a common element pertinent to the analysis of crime location in relation to the home of the offender. We confirm in this way directional bias in criminal activity as a consistent feature of crime data. We also show that directional bias is not a monolithic attribute for all municipalities.

Data and methods

Data

Data used in this study were provided by the Royal Canadian Mounted Police (RCMP) in British Columbia. British Columbia has approximately 4.1 million residents and a total of 186 police jurisdictions. The RCMP is responsible for policing 174 of the 186 British Columbia police jurisdictions—67 percent of the provincial population, approximately 2.7 million persons. The incident-based data used in the analyses below are extracted from the RCMP Police Information Retrieval System (PIRS) (for details about PIRS, see RCMP 2005). All data are extracted from August 01, 2001 through July 31, 2006. These files contain the complete set of incidents dealt with by the RCMP during these five years. Within these files, details regarding the offense event, such as location, type of crime, and time, are

included. Linked to the events are the people involved in the event, their role, and home address, amongst other information.

The PIRS database contains information for approximately 5 million negative contacts with the police involving approximately 9 million individuals (offenders, victims, complainants, and witnesses) over the five available years. From this dataset, the details of all repeat offenders who were charged or had charges recommended against them in at least 5 burglaries or thefts were analyzed. This yielded 25 376 offenders for the entire province.

Despite the PIRS database being large and there being 174 different police jurisdictions reporting to it, they are tabulated from *one* police agency or reporting body. Unlike the National Incident Based Reporting System (NIBRS) database in the United States that combines data from thousands of enforcement agencies (National Archive of Criminal Justice Data 2010), the RCMP data minimizes inconsistencies in the reporting of criminal incidents because it is based on a single collection procedure. From this dataset, property crime incidents in five municipalities were selected. These include three within the Metro Vancouver region (Coquitlam, Maple Ridge, and Surrey), one municipality outside the Metro Vancouver region (Prince George), and one municipality on Vancouver Island (Nanaimo). These were chosen to give the analysis a mixture of dense urban and suburban contexts to test the commonality of directionality in varying types of related neighbourhoods. Coquitlam and Maple Ridge are relatively small municipalities with approximately 115 000 and 69 000 persons respectively. Surrey, on the other hand, is a city of approximately 400 000 persons. Prince George is a municipality of 71 000 persons and Nanaimo is a municipality of 79 000 persons.

The three municipalities in Metro Vancouver share a set of similar characteristics: urban sprawl, light industry, strip development and malls, apartments, and single family dwellings, but the locations of these facilities are quite different for each municipality. Coquitlam essentially has one commercial district centred on a large shopping area. The area also contains a major transportation hub, with a direct train-line to downtown Vancouver; a library; a college campus; and a sports complex. Because of its size, this commercial district not only attracts residents of Coquitlam but also residents from neighbouring municipalities. Maple Ridge is one of these neighbouring municipalities that is predominantly residential, but also contains a shopping district. Maple Ridge is now connected to both Coquitlam and Surrey by bridges. In contrast, Surrey has multiple commercial districts and regional shopping areas, each large enough to attract residents from neighbouring municipalities. This is, in part, because of Surrey's greater population. Prince George and Nanaimo are included to provide more non-metropolitan examples of the importance of directionality.

Visualizing directional bias

The visualization procedure used here employs a short arrow for each criminal incident. This is a similar procedure to flow maps commonly used to represent flows of traffic, immigration, and international trade—see Dent (1999) for numerous examples of these maps. Each arrow's butt is placed at the location of the offender's home and points in the direction of the criminal incident. Because of the number of incidents, for ease of visualization, arrows do not extend to the location of the crime incident.

In order to differentiate between classes of data, a color scheme has been adopted for maps with many arrows in close proximity: arrows pointing south have a green dot on them; arrows pointing north have a red dot on them; arrows pointing west have a blue dot on them; arrows pointing east have a yellow dot on them; and arrows pointing north-east, for example, have an orange dot on them, similarly for other direction combinations see the online version of this article for the color maps.

The resulting maps are inspected for color similarity of adjacent arrows to investigate directional bias for multiple offenders. If color similarity of adjacent arrows is present, offenders located close to one another prefer the same direction when travelling to crime.

The visualization of criminal directionality

Criminal directional bias in Coquitlam is shown in Figure 2. It is clear with this visualization

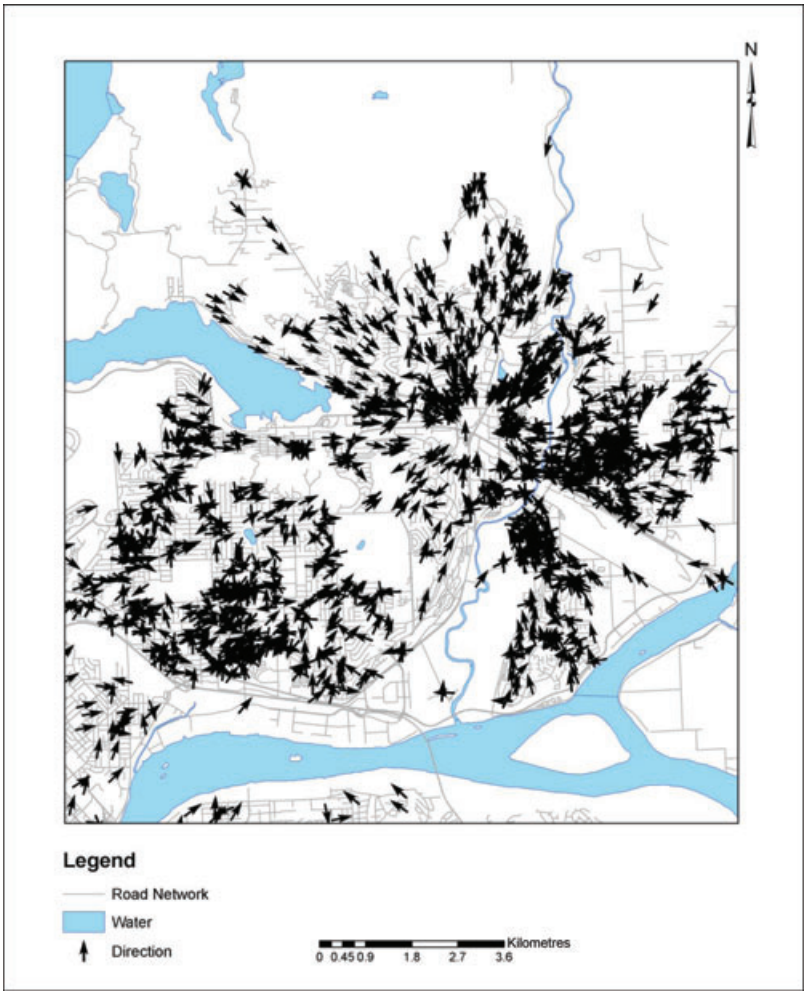

Figure 2
Directionality visualization, Coquitlam.

that directional bias is quite strong in the municipality of Coquitlam. This is particularly the case in the north-eastern section of the municipality. The vast majority of offenders travel towards (but not necessarily to) Coquitlam Centre, a major shopping district in Coquitlam. Also worthy of note is that Coquitlam Centre is just one of many shopping malls in this area. The core-shopping district is three kilometres long and up to two kilometres wide. This provides ample opportunity for the various classifications of theft under analysis.

This opportunity is easily understood with local knowledge of the area. To the north of Coquitlam Centre the land use is dominantly residential. Consequently, if an offender wishes to commit crimes other than residential burglary and automotive-related theft, a journey must take place and the closest set of opportunities in Coquitlam is the Coquitlam Centre and its immediate surrounding area. As shown by Kinney et al. (2008), this type of land use is a major attractor for criminal activities.

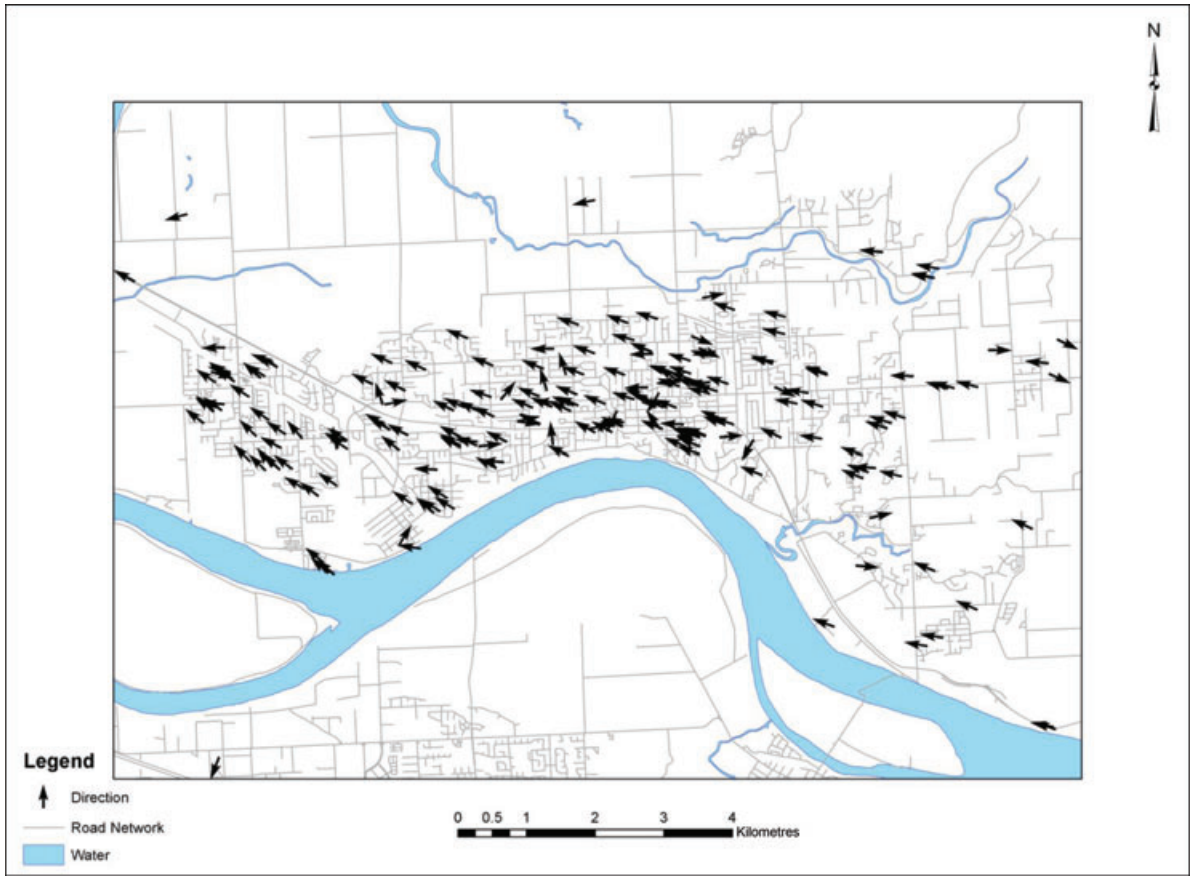

Figure 3
Directionality visualization, Maple Ridge.

The importance of regional shopping centres is more evident for Maple Ridge (Figure 3). This visualization of directionality bias shows a western movement of offenders. Maple Ridge and the municipality on its western border, Pitt Meadows, are dominantly residential communities. It should not, therefore, be a surprise that the offenders in this municipality travel toward Coquitlam in order to commit their offenses.

However, it is possible that the Maple Ridge offenders were travelling to the shopping district in Pitt Meadows, outlined in Figure 3. We argue that this is not the case. Close inspection of the arrows in Figure 3 reveals that the direction of travel is dominantly northwest. If these offenders were travelling toward the shopping district in Pitt Meadows the direction of travel would be due west or even south west. As such, the attractiveness of Coquitlam Centre, because of its opportunities, is strong enough to draw offenders from another municipality and across a bridge. Of course, we must be cautious in our interpretations here as we are only analyzing the direction of travel for the offense. But given our knowledge of the area and its criminal opportunities it is likely that offenders are travelling to the Coquitlam Centre area to search for criminal opportunities.

The directional bias visualization for Surrey (Figure 4), is different from Coquitlam or Maple

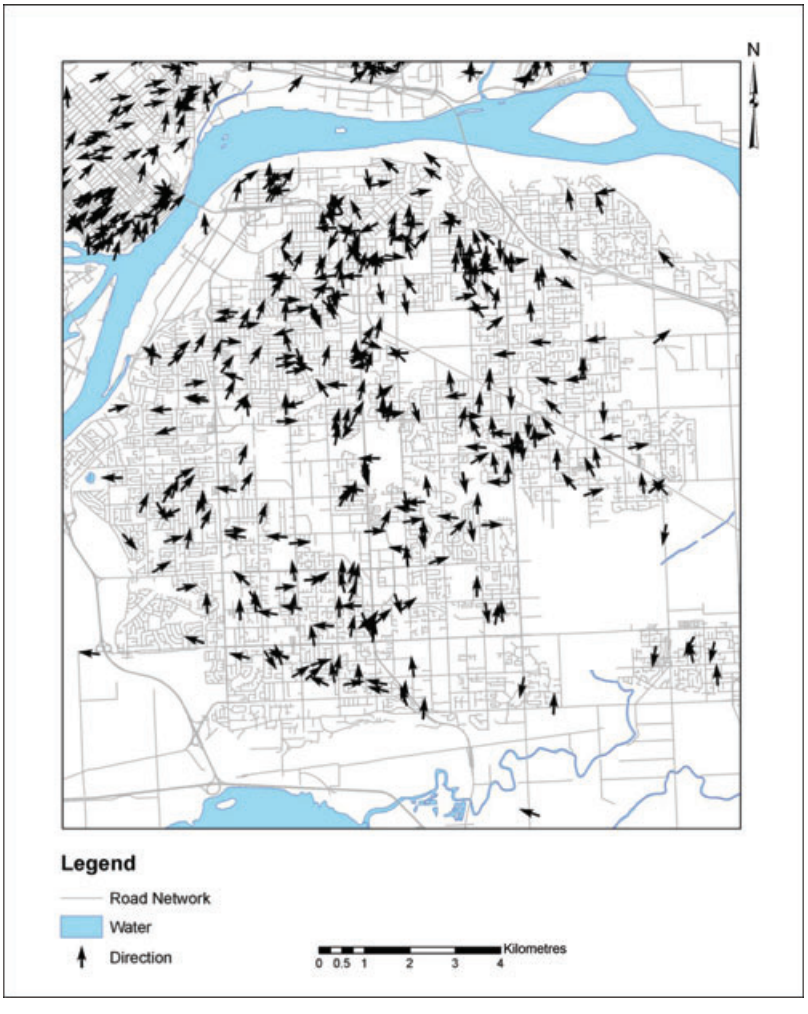

Figure 4
Directionality visualization, Surrey.

Ridge. In fact, there is no overall directional bias for the municipality of Surrey. Though there is no global directional bias for all offenders, the presence of a directionality bias should not be dismissed. In contrast to Coquitlam and Maple Ridge, Surrey has seven regional shopping centres and multiple commercial districts, each large enough to attract offenders from neighbouring municipalities. Consequently, we propose that Surrey has local convergence areas of directional bias rather than global convergence of directional bias. Such a proposition should not be considered purely speculation because Surrey is four times the size of Coquitlam; in fact, the presence of a global convergence of directional bias in such a large municipality with such a large population would be questionable. This is, of course, an empirical question that we leave as a direction for future research.

The results for Prince George (Figure 5), are similar to those of Coquitlam. The primary difference, though not evident from the

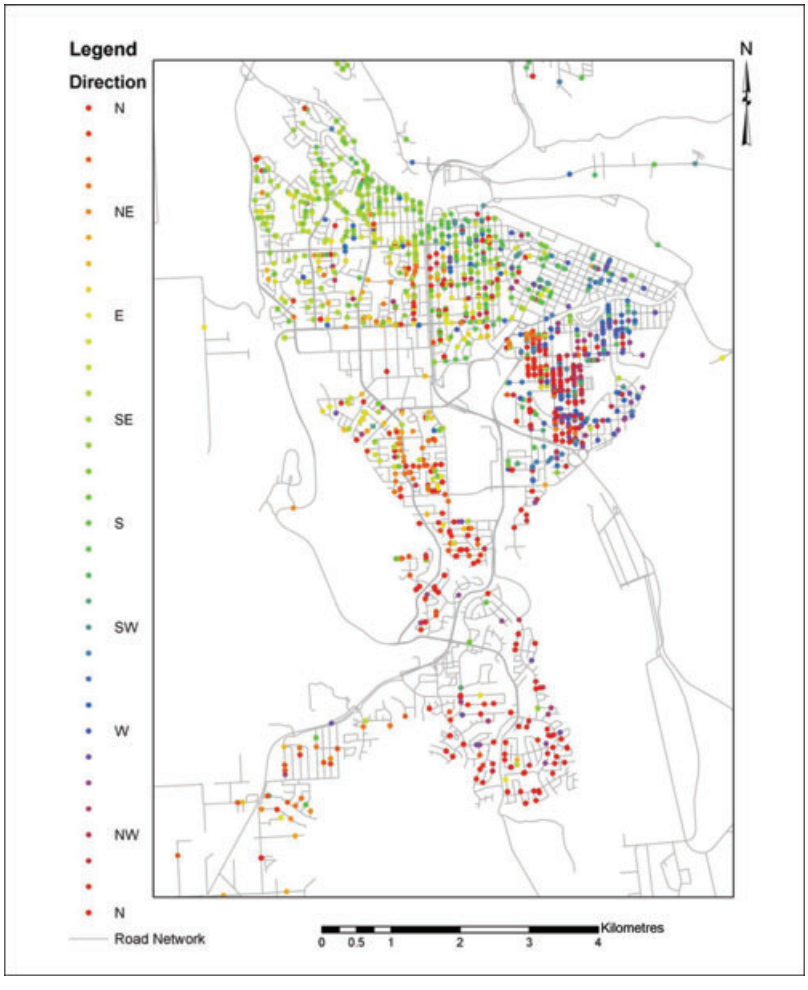

Figure 5
Directionality visualization, Prince George.

visualization, is that the Prince George results are driven by offenders converging in the downtown urban area of Prince George rather than a shopping centre, *per se*. Once again, this highlights the importance of understanding place and criminal opportunities in efforts to understand the geography of crime.

Lastly, the results for Nanaimo are shown in Figure 6. The same general pattern is present in Nanaimo, crime in the downtown urban area, though the nature of this municipality is somewhat different. Nanaimo does contain a city centre that is drawing many offenders in its direction, but the opportunity surface in Nanaimo is far from restricted to this city centre. Rather, Nanaimo has a highway that runs through it northeast to southwest. Much of this highway within the municipal boundaries of Nanaimo is a strip mall. In fact, the largest shopping centre in Nanaimo is located at the northern-most boundary of the municipality. Not only is the north-end of Nanaimo home to this large shopping centre, but also the wealthier residences in the municipality. Regardless, the "traditional" locations for

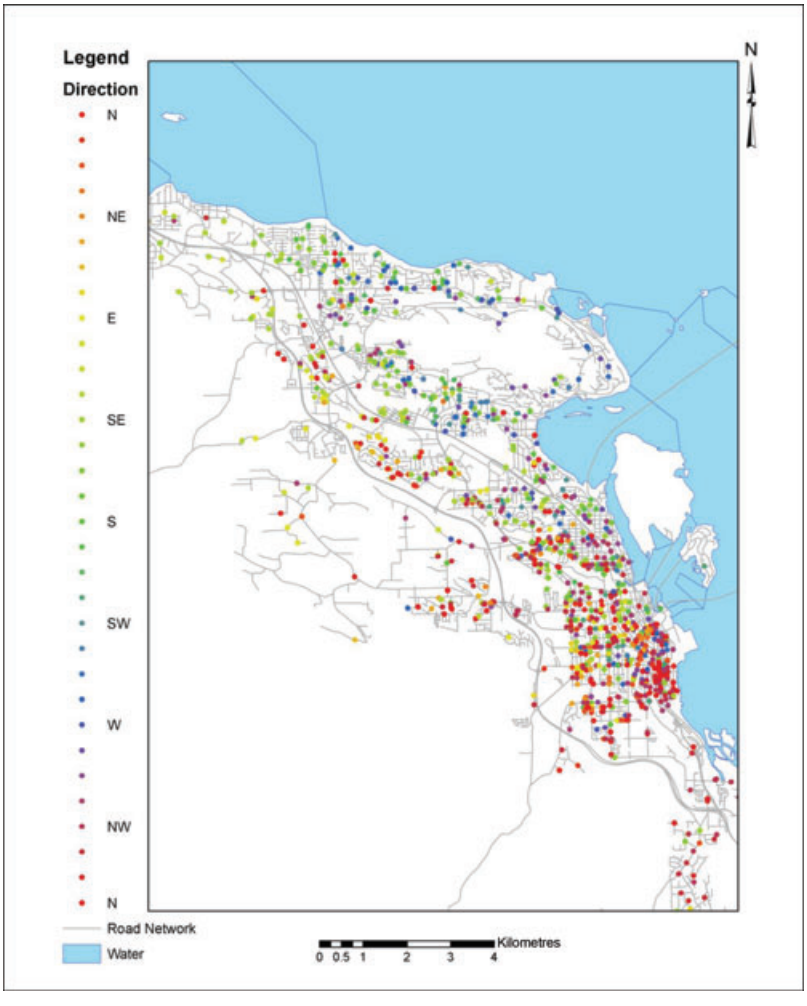

Figure 6
Directionality visualization, Nanaimo.

criminal opportunity in this municipality remain intact, showing the importance of path dependency in the geography of crime—geographical patterns are difficult to disrupt.

Conclusions

This article provides a procedure for visualizing the directional bias of criminal activities. Through this visualization procedure, we show that most municipalities under study exhibit a global directional bias for all offenders. In the case of Maple Ridge and Pitt Meadows, that global directional bias extends into another municipality. As such, this article contributes to the directionality literature by showing the directionality bias of a large number of offenders on one map. Though the information provided in these maps is different, our visualization procedure well complements the protractor method developed by Rengert and Wasilchick (1985, 2000).

That the presence of opportunity dictates the directionality bias of offenders is evident from the figures, particularly for those municipalities with a global convergence of directional bias. City centres, downtown areas, and shopping districts disproportionally draw offenders to them because of criminal opportunity. As such, the geography of land use is an important factor in understanding crime patterns (Kinney et al. 2008).

Further research on directionality should be undertaken in a number of areas. First, because of the large number of observations in the present data set, the strength of directionality may be investigated using relatively fine crime classifications. This is particularly important for crimes with relatively low incidence rates. Such an investigation may not necessarily generate mappable output, but could allow for the quantification of directional bias in criminal activities. Second, an empirical investigation into global versus local convergence is in order. If the appearance of randomness in Surrey can be explained considering local convergence of directional bias, understanding local criminal opportunities is critical for understanding the geography of crime. And third, micro-level analyses of directional bias are necessary to investigate the importance of direction for individual offenders. Such investigations may consider if offenders have more than one directional preference (on the way to work *and* on the way to school, for example), or whether or not directional bias is driven by highly specific crime attractors and generators (Brantingham and Brantingham 1995) or more general area characteristics.

Acknowledgements

This work was carried out in the ICURS Laboratory at Simon Fraser University under the terms of a joint Memorandum of Understanding between the Institute for Canadian Urban Research Studies, Simon Fraser University, "E"-Division of the Royal Canadian Mounted Police, and the British Columbia Ministry of Public Safety and Solicitor General.

References

Andresen, M. A., and N. Malleson. 2011. Testing the stability of crime patterns: Implications for theory and policy. *Journal of Research in Crime and Delinquency* 48(1): 58–82.

Bernasco, W., and R. Block. 2009. Where offenders choose to attack: A discrete choice model of robberies in Chicago. *Criminology* 47(1): 93–130.

Brantingham, P. L., and P. J. Brantingham. 1981. Notes on the geometry of crime. In *Environmental criminology*, ed. P. J. Brantingham and P. L. Brantingham. Beverly Hills, CA: Sage Publications, 27–53.

———. 1984. *Patterns in crime*. New York: Macmillan.

———. 1993. Nodes, paths and edges: Considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology* 13(1): 3–28.

———. 1995. Criminality of place: Crime generators and crime attractors. *European Journal on Criminal Policy and Research* 3(1): 5–26.

Burgess, E. W. 1916. Juvenile delinquency in a small city. *Journal of the American Institute of Criminal Law and Criminology* 6(5): 724–728.

Castanzo, C. M., W. C. Halperin, and N. Gale. 1986. Criminal mobility and the directional component in journeys to crime. In *Metropolitan crime patterns*, ed. R. M. Figlio, S. Hakim, and G. F. Rengert. Monsey, NY: Criminal Justice Press, 73–95.

Chainey, S., and J. H. Ratcliffe. 2005. *GIS and crime mapping*. Chichester, UK: John Wiley & Sons.

Clarke, R. V. G., and D. B. Cornish. 1985. Modeling offenders' decisions: A framework for research and policy. *Crime and Justice: An Annual Review of Research* 6: 147–185.

Cohen, L. E., and M. Felson. 1979. Social change and crime rate trends: A routine activity approach. *American Sociological Review* 44(4): 588–608.

Cornish, D. B., and R. V. Clarke. 1986. *The reasoning criminal: Rational choice perspectives on offending*. New York: Springer-Verlag.

Costello, A., and P. Wiles. 2001. GIS and the journey to crime: An analysis of patterns in South Yorkshire. In *Mapping and analysing crime data: Lessons from research and practice*, ed. A. Hirschfield and K. Bowers. London, UK: Taylor and Francis, 27–60.

Dent, B. D. 1999. *Cartography: Thematic map design*. 5th ed. Boston: McGraw-Hill.

Eck, J. E., and D. Weisburd, eds. 1995. *Crime prevention studies*. Volume 4*: Crime and place*. Monsey, NY: Criminal Justice Press.

Esri. n.d. Law enforcement. http://www.esri.com/industries/public-safety/law-enforcement/.

Felson, M., and L. E. Cohen. 1980. Human ecology and crime: a routine activity approach. *Human Ecology* 8(4): 398–405.

———. 1981. Modeling crime trends: A cumulative opportunity perspective. *Journal of Research in Crime and Delinquency* 18(1): 138–164.

GeoVISTA. 2010. GeoVISTA Center: About CrimeViz. http://www.geovista.psu.edu/CrimeViz/.

Godwin, M. 2001. Geographical profiling. In *Criminal psychology and forensic technology: A collaborative approach to effective profiling*, ed. G. M. Godwin. Boca Raton, FL: CRC Press.

Guerry, A-M. 1833. *Essai sur la Statistique Morale de la France*. Paris: Crochard.

Horton, F. E., and D. R. Reynolds. 1971. Effects of urban spatial structure on individual behaviour. *Economic Geography* 47(1): 36–48.

Kinney, J. B., P. L. Brantingham, K. Wuschke, M. G. Kirk, and P. J. Brantingham. 2008. Crime attractors, generators and detractors: Land use and urban crime opportunities. *Built Environment* 34(1): 62–74.

LeBeau, J. L. 1987. The journey to rape: Geographical distance and the rapist's method of approaching the victim. *Journal of Political Science and Administration* 15(2): 129–136.

Lowe, J. C., and S. Moryadas. 1975. *The geography of movement*. Boston: Houghton Mifflin.

Lynch, K. 1960. *The image of the city*. Cambridge, MA: MIT Press.

National Archive of Criminal Justice Data. 2010. National Incident-Based Reporting System resource guide. http://www.icpsr.umich.edu/icpsrweb/NACJD/NIBRS/.

Phillips, P. D. 1980. Characteristics and typology of the journey to crime. In *Crime: A spatial perspective*, ed. K. D. Harries. New York: Columbia University Press, 167–180.

Pyle, G. F., E. W. Hanten, P. G. Williams, A. L. Pearson II, J. G. Doyle, and K. Kwofic. 1974. *The spatial dynamics of crime*. Chicago, IL: University of Chicago Press.

Quetelet, L. A. J. 1831 [1984]. *Research on the propensity for crime at different ages*. Cincinnati, OH: Anderson Publishing.

———. 1842. *A treatise on man and the development of his faculties*. Edinburgh: W. and R. Chambers.

Ratcliffe, J. H. 2002. Aoristic signatures and the spatiotemporal analysis of high volume crime patterns. *Journal of Quantitative Criminology* 18(1): 23–43.

———. 2004. Crime mapping and the training needs of law enforcement. *European Journal on Criminal Policy and Research* 10(1): 65–83.

———. 2006. A temporal constraint theory to explain opportunity-based spatial offending patterns. *Journal of Research in Crime and Delinquency* 43(3): 261–291.

Ratcliffe, J. H., and M. J. McCullagh. 2001. Chasing hosts? Police perception of high crime areas. *British Journal of Criminology* 41(2): 330–341.

RCMP (Royal Canadian Mounted Police). 2005. Police Reporting and Occurrence System (PROS). http://www.rcmp-grc.gc.ca/pia-efvp/pros-sirp-eng.htm.

Rengert, G. F. 1989. Behavioural geography and criminal behaviour. In *The geography of crime*, ed. D. J. Evans and D. T. Herbert. New York: Routledge, 161–175.

Rengert, G. F., A. R. Piquero, and P. R. Jones. 1999. Distance decay re-examined. *Criminology* 37(2): 427–445.

Rengert, G. F., and J. Wasilchick. 1985. *Suburban burglary: A time and a place for everything*. Springfield, IL: Charles C. Thomas.

———. 2000. *Suburban burglary: A tale of two suburbs*. Springfield, IL: Charles C. Thomas.

Rossmo, D. K. 2000. *Geographic profiling*. Boca Raton, FL: CRC Press.

Shaw, C. R., and H. D. McKay. 1931. *Social factors in juvenile delinquency*. Washington, DC: US Government Printing Office.

———. 1942. *Juvenile delinquency and urban areas: A study of rates of delinquency in relation to differential characteristics of local communities in American cities*. Chicago, IL: University of Chicago Press.

Sherman, L. W., P. R. Gartin, and M. E. Buerger. 1989. Hot spots of predatory crime: Routine activities and the criminology of place. *Criminology* 27(1): 27–56.

Smith, W. R., S. G. Frazee, and E. L. Davidson. 2000. Furthering the integration of routine activity and social disorganization theories: Small units of analysis and the study of street robbery as a diffusion process. *Criminology* 38(2): 489–524.

Taylor, R. B. 1997. Social order and disorder of street blocks and neighborhoods: Ecology, microecology, and the systemic model of social disorganization. *Journal of Research in Crime and Delinquency* 34(1): 113–155.

Tufte, E. R. 2001. *The visual display of quantitative information*. 2nd ed. Cheshire, CT: Graphics Press.

van Koppen, P. J., and J. W. De Keijser. 1997. Desisting distance decay: On the aggregation of individual crime trips. *Criminology* 35(3): 505–515.

Weisburd, D., W. Bernasco, and G. J. N. Bruinsma. 2009. *Putting crime in its place: Units of analysis in geographic criminology*. New York: Springer.

Weisburd, D., S. Bushway, C. Lum, and S-M. Yang. 2004. Trajectories of crime at places: A longitudinal study of street segments in the City of Seattle. *Criminology* 42(2): 283–321.

White, R. C. 1932. The relation of felonies to environmental factors in Indianapolis. *Social Forces* 10(4): 498–509.

Wiles, P., and A. Costello. 2000. *The "road to nowhere": The evidence for travelling criminals*. Home Office Research Study 207. London, UK: Home Office, Research, Development and Statistics Directorate.

Wolff, M., and H. Asche. 2009. Geovisualization approaches for spatio-temporal crime scene analysis: Towards 4D crime mapping. In *Lecture notes in computer science: Computational forensics*, ed. Z. Geradts, K. Franke, and C. Veenman. Berlin: Springer-Verlag, 78–89.

Wolpert, J. 1964. The decision process in spatial context. *Annals of the Association of American Geographers* 54(4): 537–558.